



GE Global Research

Microturbine Developments at GE

***Advanced
Integrated
Microturbine
System***

Karl Sheldon
Project Leader

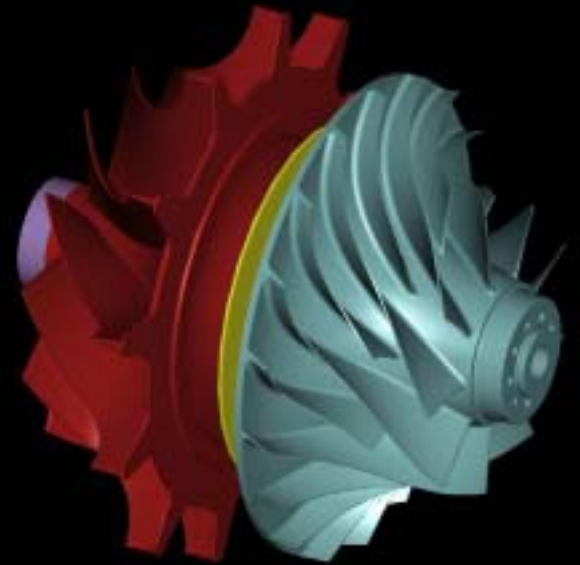
*Distributed Energy Peer Review
December 3rd, 2003*





Outline

- Project Overview
- Conceptual Design
- Component & System Design
- Fabrication
- Integration
- Ceramic Activities
- Summary





Project Overview

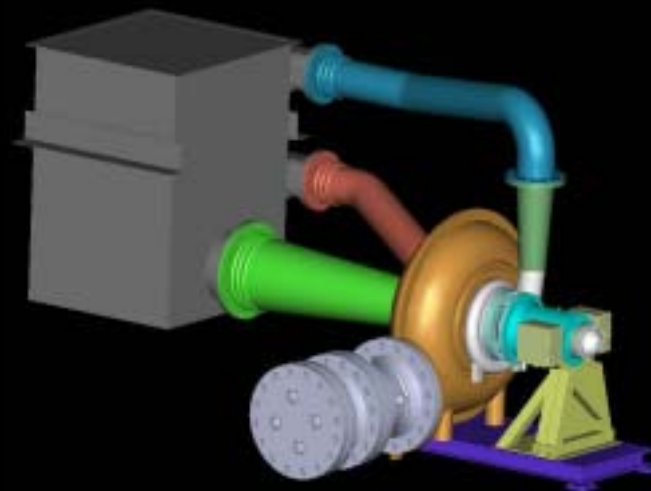
OBJECTIVE

- Next generation microturbine system
- Improve efficiency, cost, and emissions
- Current and emerging distributed generation markets
 - Fuel Cell Bottoming Cycle
 - Combined Heating, Cooling and Power Systems
 - Opportunistic Fuel Utilization

CTQ'S

- 35% Efficient Design w/ Growth to 40%
- 175 kW Output with growth to +250 kW
- ≤ 10 ppm NOx on Natural Gas ✓
- ≤ 10 ppm CO on Natural Gas ✓
- $\leq \$500/\text{kW}$ unit cost
- 11,000 hour maintenance interval
- 45,000 hour life

Program Milestone	Scheduled Completion Date	Status
Market Study	Dec-00	Complete
Conceptual Design	Apr-01	Complete
Component Design	Nov-02	Complete
System Design	May-03	Complete
Component Fabrication	Aug-03	Delayed
System Integration	Oct-03	Delayed
Laboratory Evaluation	Jan-04	Planned
Final Business Plan	Mar-04	Planned
Demonstration	Sep-04	Planned



PROJECT TEAM

GE Global Research (Niskayuna, Bangalore, Shanghai)
GE Power Systems (GEPS)
GE Industrial Systems (GEIS)
PCC, Port City Machine & Tool, Turbo Genset Company
Kyocera Industrial Ceramics Corp.
Oak Ridge National Laboratory

PROJECT STATUS - Red/Yellow/Green

- Vendors Dependent Tasks

Status

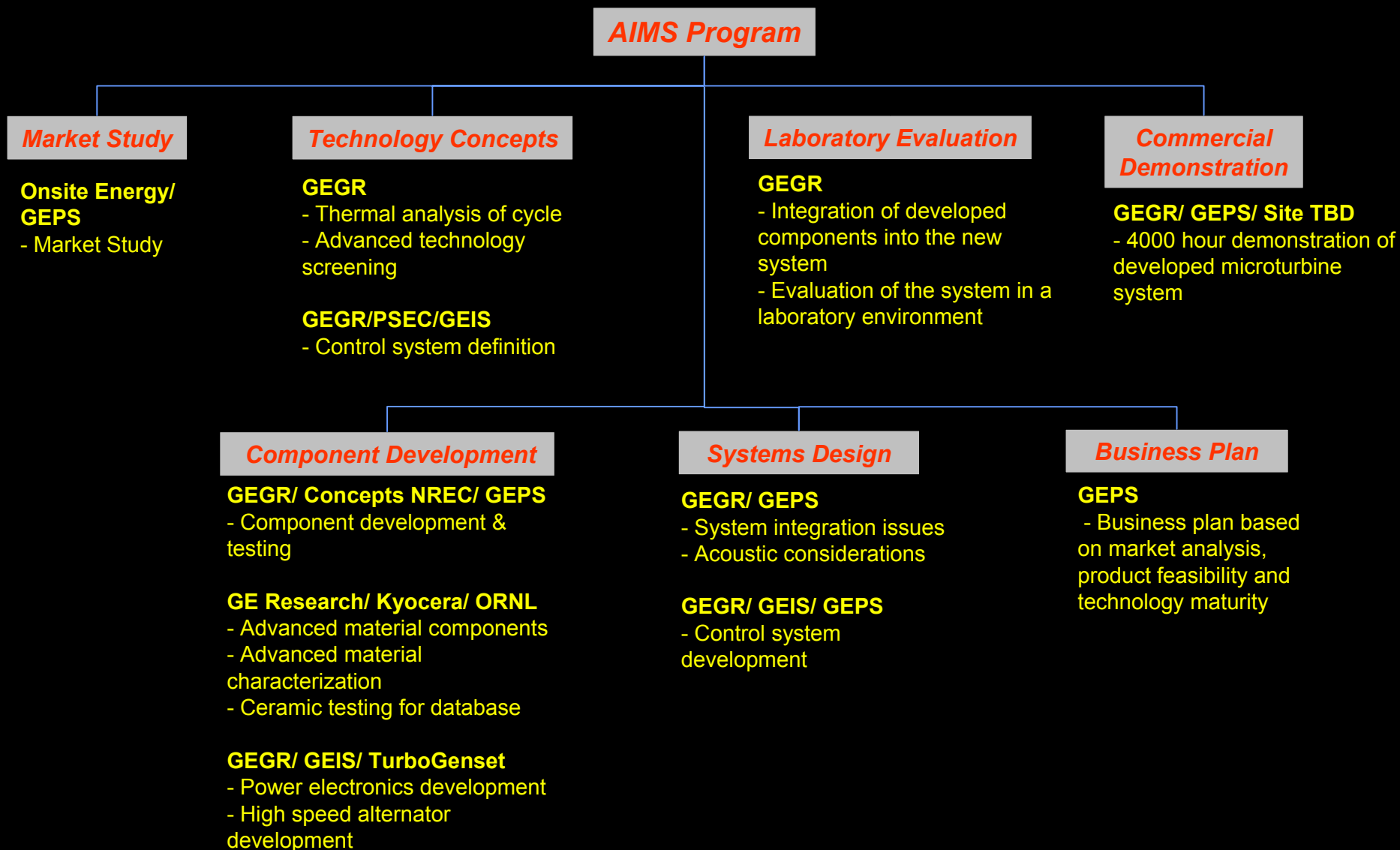
Yellow

PATENTS/PAPERS

- 2 ASME Presentation, June 2002 & June 2003
- 1 Journal Publication – “Modern Power Systems”, Spring 2002
- Over 35 Patent Disclosures with 3 Filings



Program Team



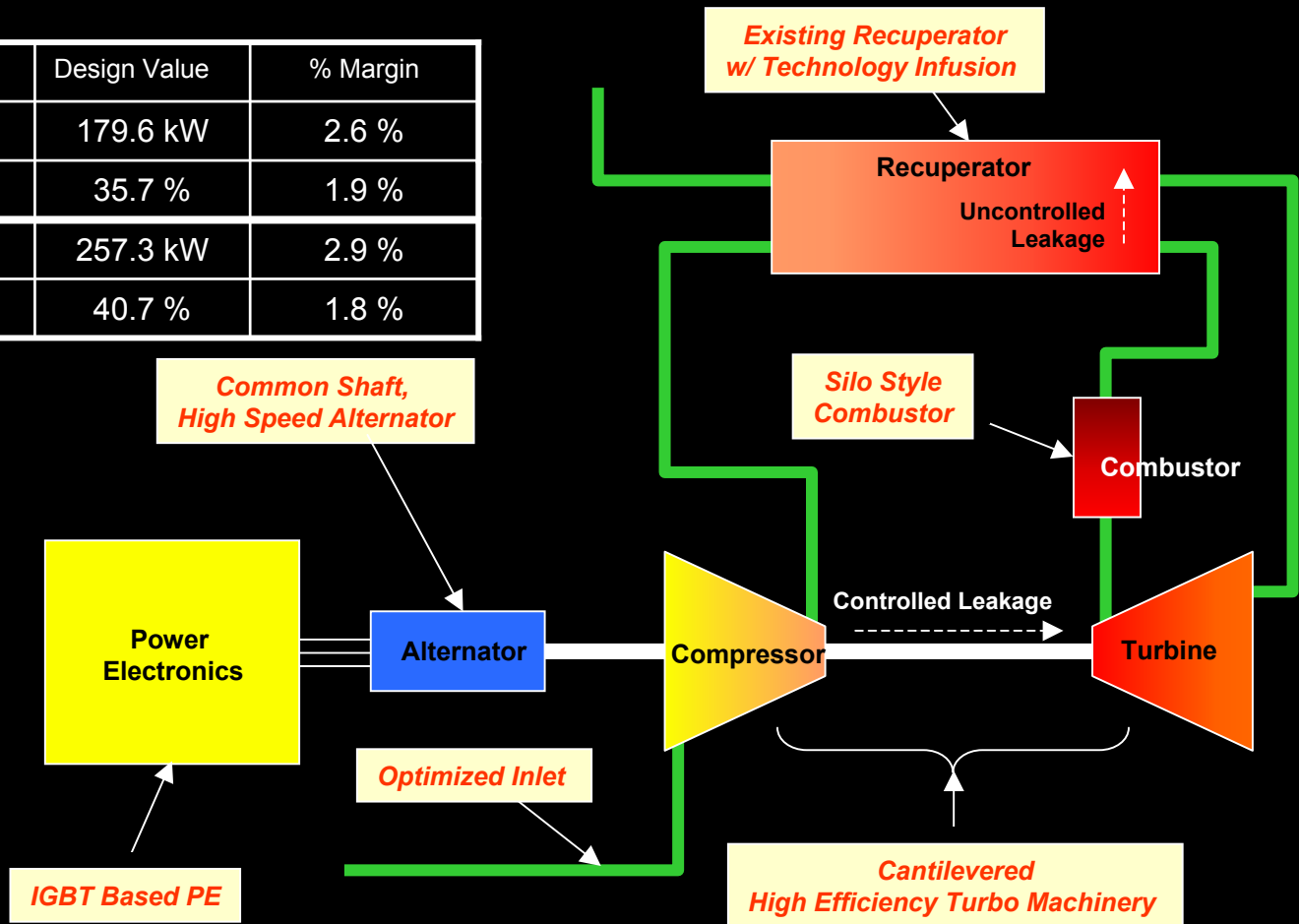


Conceptual Design

TASK FOCUS:

- Determine system thermal design to achieve the 40% efficiency target
 - Reduce the operating temperature of the cycle to “metallic” levels
- *this process allows for proof of component technologies prior to the introduction of advanced materials*

	Target Value	Design Value	% Margin
Cycle Output	175 kW	179.6 kW	2.6 %
Cycle Efficiency	35 %	35.7 %	1.9 %
Cycle Output	250 kW	257.3 kW	2.9 %
Cycle Efficiency	40 %	40.7 %	1.8 %

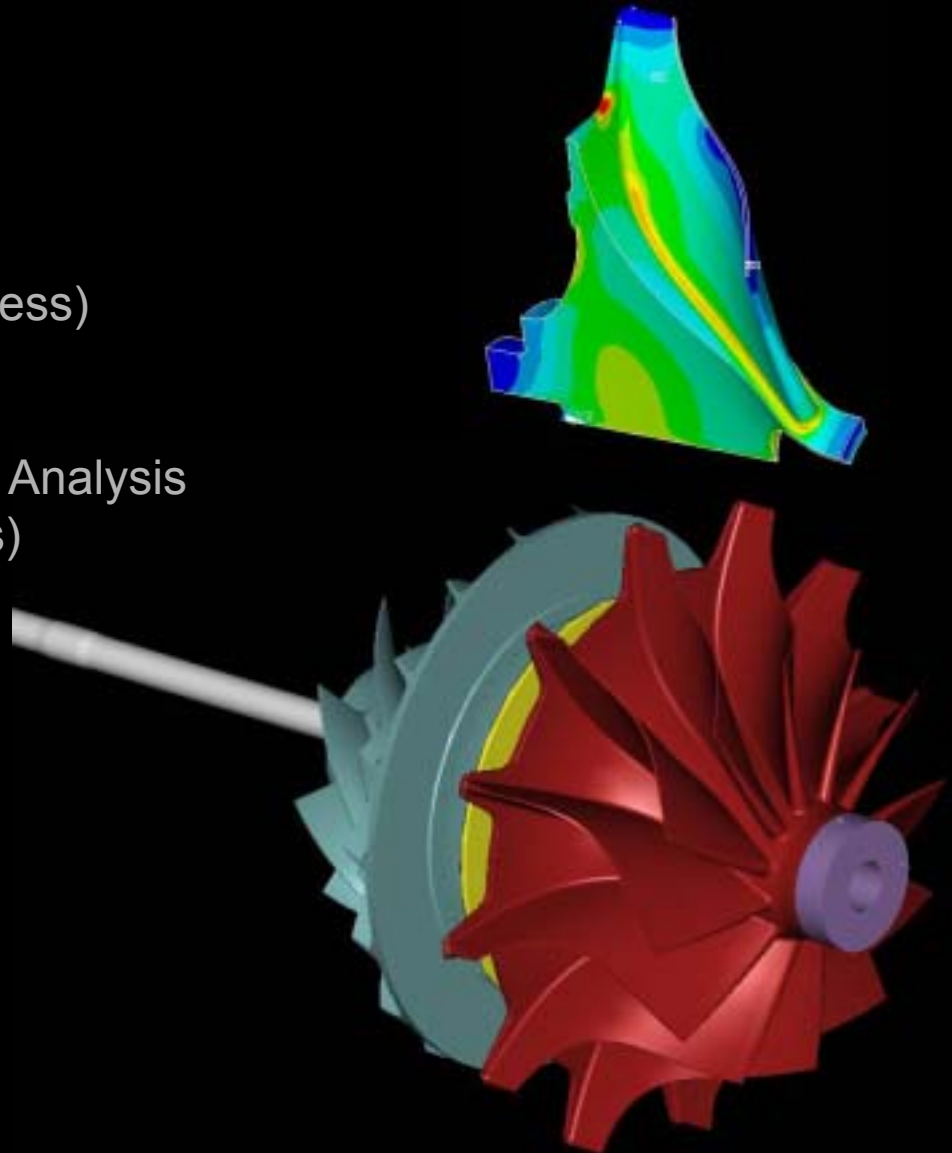




Component Design - Turbomachinery

ACTIVITIES:

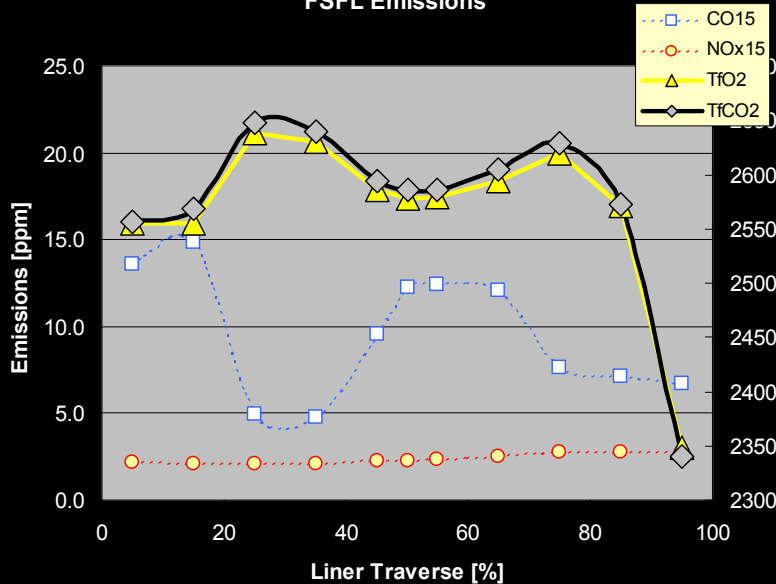
- Component Design Targets Set
- 1D Analysis (Flow & Stress)
- Rotor Dynamic Analysis
- Materials Down Selection
- 1st Pass 3D Analysis (Flow & Stress)
- Analysis of Results
- Modifications/ Redesigns
- Stationary Component Design & Analysis
- Final 3D Analysis (Flow & Stress)
- Final Rotor Dynamic Analysis
- Hardware Procurement
- Experimental Evaluation
 - Integration with MT System
 - Evaluation





Component Design - Combustion

FSFL Emissions



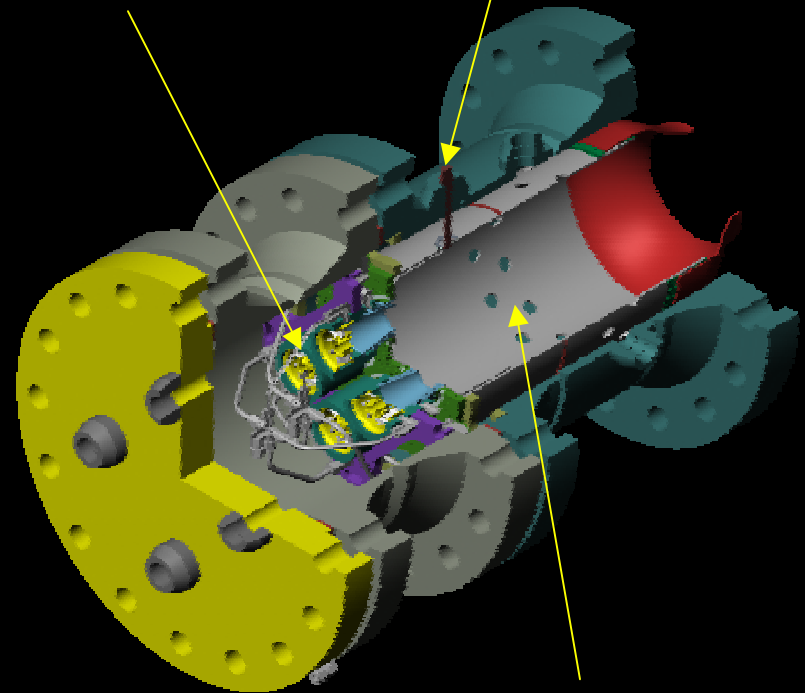
Combustor Performance:

NOx (15% O₂) = 3.4 ppm

CO (15% O₂) = 8.4 ppm

4 Cup Premixed
System w/ Diffusion

UNISON Igniter



Reverse Flow,
Silo Combustor



Component Design - Recuperator

TASK FOCUS:

Infuse GE expertise of gas turbine heat transfer into existing recuperator technology to build a better system.

ACTIVITIES:

- Performance Design Targets Set
- Reverse Engineered Existing Recuperator – Validated with Experiments
- Preliminary Sizing of Recuperator
- Potential Heat Transfer Enhancement Technologies Identified
- Design Impact of Technologies Determined
- Capable Vendors Identified
- Vendor Finalized
- Initial Hardware Procurement

➔ New Technology Design Incorporation

- New Technology Sample Procurement
- New Technology Sample Experimental Evaluation
- New Technology Prototype Procurement
- Experimental Evaluation

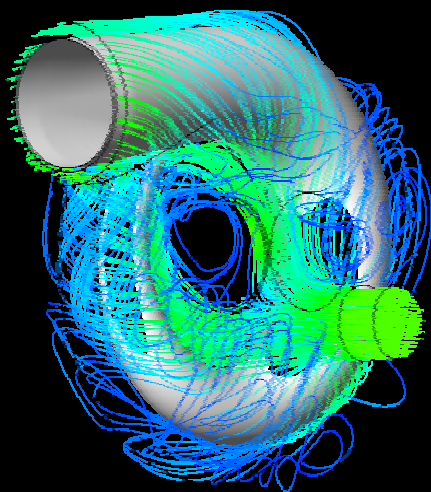




System Design

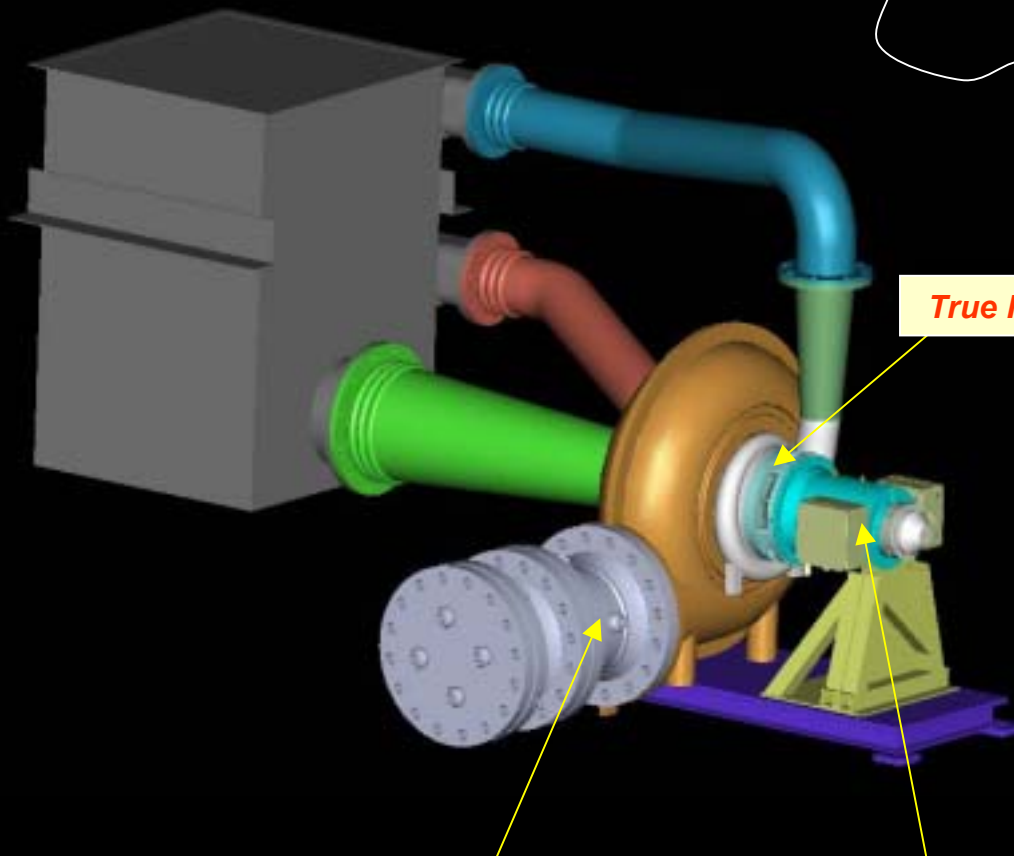
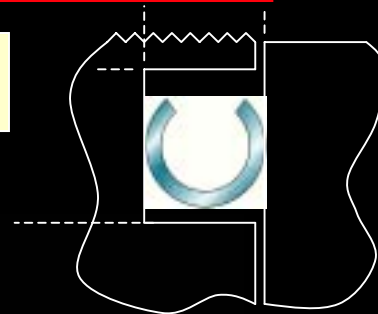


Tight Tolerance Specifications



Minimizing Aero Losses

**Advanced Seals
Designs**



True Radial Inflow

**High Firing
Temperature**

**Efficient High
Speed Alternator**



Component Fabrication

Digital

Castings

- Complete Digital Design
- Optimizations performed at the system level
- Design transferred as a 3D object for casting
- Design Input From All Parties: *(chief engineers, casting vendors, machining vendors, welders, etc.)*
- As-cast SLA finish and dimensions better than expected





Component Fabrication





Component Fabrication

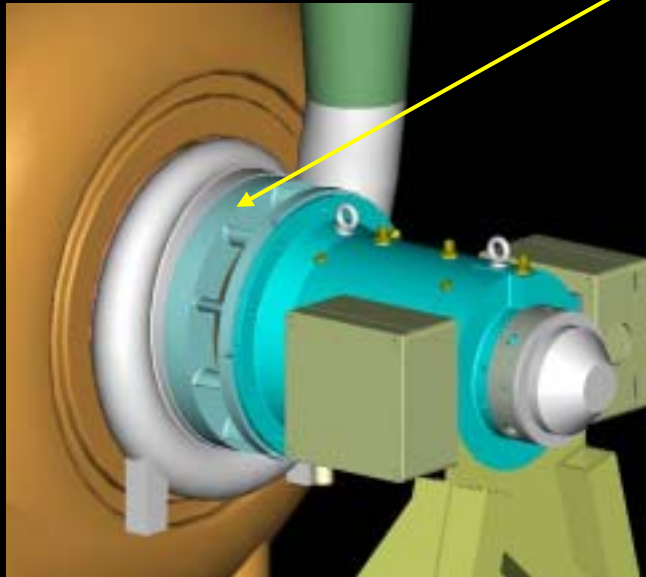
Diffuser in CMM



Inlet Mounted to Compressor Scroll

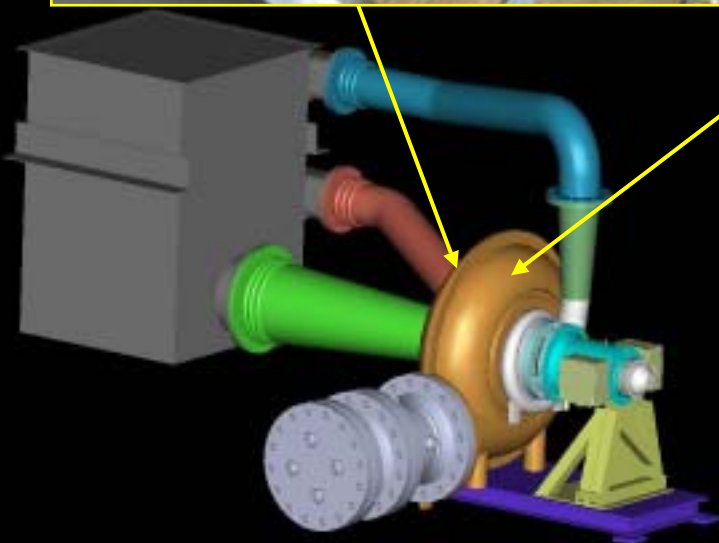


Rotating Components



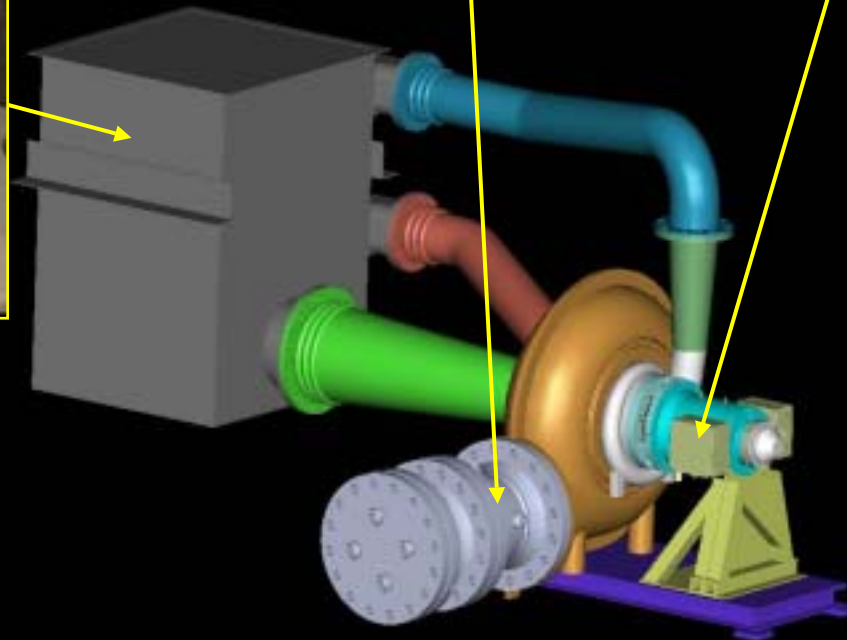


Component Fabrication





System Integration – Core



* Highest Technical Risk



System Integration – Power Electronics

PE ACTIVITIES:

- Specifications & Topology Tradeoffs
- Generator Vendor Selection
- Power Electronic Simulations
- Auxiliary System Design
- FMEA
- Component Fabrication
- System Tests

➔ Integration w/ Turbine System

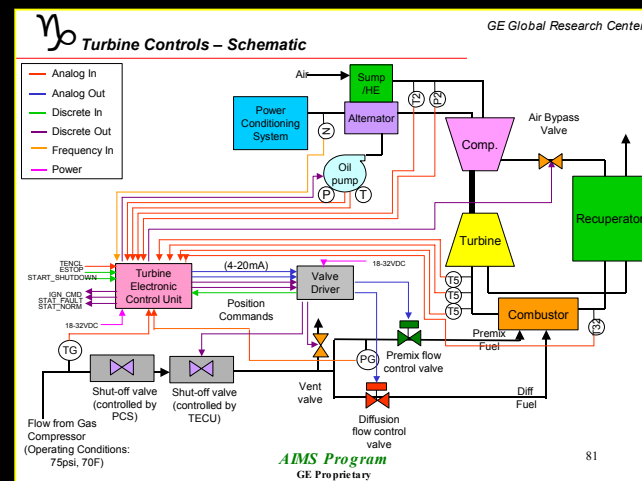


**Cabinet For Filters, Controllers
And Electrical BoP**

CONTROLS ACTIVITIES:

- Control Requirements
- System Simulations
- Platform Selection
- Algorithm & Code Development
- Communication & HMI Development
- Hardware Procurement
- Test Sensors and Actuators
- Combustion Testing for Fuel Schedules
- Communication Test with Power Electronics

➔ Integration w/ Turbine System





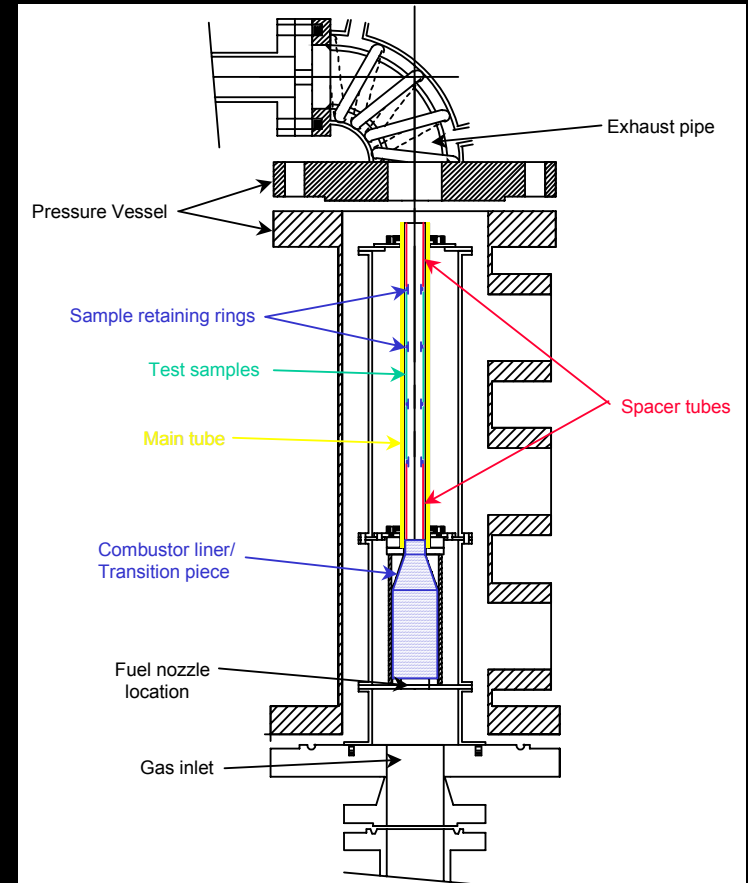
Ceramic Activities

Testing in simulated microturbine environment

- Important for reliable design of ceramic components
- Viable screening tool (instead of engine testing) for material development

Exposure Tests

- Rig operating capabilities:
 - $T=1200^{\circ}\text{C}$
 - $V=120\text{ m/s}$
 - $P_{\text{tot}} = 9\text{ atm}$; $P_{\text{H}_2\text{O}} = 1\text{ atm}$
- Test plan
 - $T=1100^{\circ}\text{C}$
 - $t= 1000\text{h}$
 - $P_{\text{tot}} = 4\text{ atm}$; $P_{\text{H}_2\text{O}} \sim 0.4\text{ atm}$
 - $V \sim 230\text{ m/s}$
- Test specimens: $100\text{ mm} \times 15\text{ mm} \times 2.2\text{ mm}$
 - SN-282
 - EBC-coated SN-282
 - Uncoated and EBC-coated Si_3N_4



Results Used To Supplement ORNL Database



Summary

- Design, build, and test a 175 kW microturbine with an electrical efficiency of ~35%. Show the path required to reach 40%
- Large, multidisciplinary team leveraging GE technology from *Industrial Systems, Aircraft Engines, and Power Systems*
- Incremental increases in performance can incur exponential costs
- Cost of casting failures greater than expected (time and money)
- Vendor dependant tasks identified as a risk early in the program – well founded
- Scheduled to begin testing in early 2004

